CHAPTER 18

CHEMICAL TREATMENT SYSTEMS

18-1. Chemical treatment system design features

This chapter presents an overview of common chemical treatment processes that may be required to maintain water, steam, and condensate utility systems in good operating condition. The descriptions in this chapter are provided as a reference for the reader in applying the terminology, uses of equipment, and recommended maintenance practices. The need for chemical treatment depends on the quality of the water supplied to the facility and the types of equipment in service at the facility. There is no one treatment program or system that is right for all facilities or systems within the facilities. The chemical treatment examples are based on the facility being supplied with water either from a municipal supply system or from a well system dedicated to the facility. The water supplied to the facility generally meets drinking water standards and is used to supply potable water and process water systems within the facility.

a. Applications. The systems for which treatment practices are discussed as follows.

(1) Well water delivered to facility domestic and industrial water reservoirs

(2) Closed-loop recirculating water systems (chilled water, recirculating cooling water, and hot water heating)

(3) Open recirculating water systems (cooling tower spray water or recirculating cooling water in an open cooling tower loop)

(4) Steam boiler system (makeup water, feedwater, and steam and condensate)

b. Water supply disinfection. Although the water supplied to the facility is already drinking water quality, additional disinfection may be required to control the growth of biological contaminants, such as algae, in the potable and industrial water reservoirs where long-term storage may provide conditions for growth. This additional disinfection may be direct treatment of the water supplied to the facility, treatment of a recirculating stream at the reservoirs, or a combination of both. Operator involvement is limited to testing the water to determine the amount of treatment required, adjusting the pump stroke and/or the hypochlorite solution strength to obtain the desired dosage, and keeping an adequate supply of hypochlorite solution in the local storage tank.

c. Process water systems. Process water refers to systems, such as chilled water systems, hot water heating systems, and recirculating water equipment cooling systems. The three primary reasons that process water chemical treatment may be required are to control corrosion, scale formation, and the growth of biological agents. Because corrosion and scale control chemicals can change the pH of the circulating water stream, the pH of a system may also require monitoring and adjustment. Process water streams may be closed-loop systems or open systems.

(1) In closed loop systems, there are negligible losses from or additions into a known volume system. Once the initial volume is chemically treated, the quality of the circulating fluid needs to be monitored on a regular basis and additional chemicals added as required to maintain recommended residual concentrations of treatment chemicals. When chemical treatment of a closed-loop water

circulating system is required, the chemicals are usually introduced into the system by means of a pot feeder. The chemical treatment can be accomplished as the system is filled or during normal operation of the system using a pot feeder in a bypass loop. A typical pot feeder fill system installation is shown on figure 18-1, and a typical pot feeder bypass installation is shown on figure 18-2.

(a) In cold service closed-loop systems, the system may only need to have chemical treatment when the system is filled initially and any time the system has been open for maintenance. Cold service recirculating systems are usually treated to prevent corrosion from dissolved oxygen. Scale formation is usually not a problem in cold systems.

(b) In warm or hot service closed-loop water circulating systems, regular monitoring and chemical additions may be required to prevent corrosion from dissolved oxygen and scale formation from precipitation of minerals in the water.

(2) In open recirculating cooling water systems there is constant loss from the system due to evaporation and a constant addition of makeup water into the system which constantly changes the quality of the recirculating stream. Also, as water evaporates from the system, impurities in the water are left behind which causes an increase in the concentration of these impurities. These impurities are generally referred to as total dissolved solids. Open systems typically control total dissolved solids by blowdown from the system. Additionally, the methods used to reduce the temperature of open recirculating water streams allow oxygen, which is a primary cause of corrosion, to be entrained in the recirculating stream.

(a) This constant change in the system quality may require frequent water quality monitoring along with the frequent addition of chemicals to control corrosion, scale formation, and growth of biological agents. Some combinations of chemicals used may also change the pH of the system significantly which will require pH monitoring and adjustment. If an open system requires chemical treatment, treatment program options range from the operator periodically sampling the water and making slug additions of chemicals into the basin to a continuous water quality analyzer controlling the operation of metering pumps which inject controlled doses of chemicals into the circulating stream to maintain a uniform water quality.

(b) A typical automated open-loop water quality monitoring and control system is shown on figure 18-3. In the example automated system, a sample stream passes through a water quality analyzer which has probes that monitor pH and conductivity (a measure of total dissolved solids). The pH meter controls a metering pump that injects a pH adjustment solution (usually an acid) into the circulating stream. The conductivity meter controls the operation of the blowdown valve. A signal from a water meter in the makeup waterline controls the corrosion inhibitor metering pump. A timer in the water quality analyzer activates the biological growth control metering pump. Some automated systems may have a corrosion sensing probe, rather than a water meter, to control the corrosion inhibitor metering pump. A likely alternate to the fully automated system is metering pumps controlled by timers. Based on a periodic water sample, the operator sets the timers and adjusts the metering pumps to provide the desired level of chemical treatment for the system.

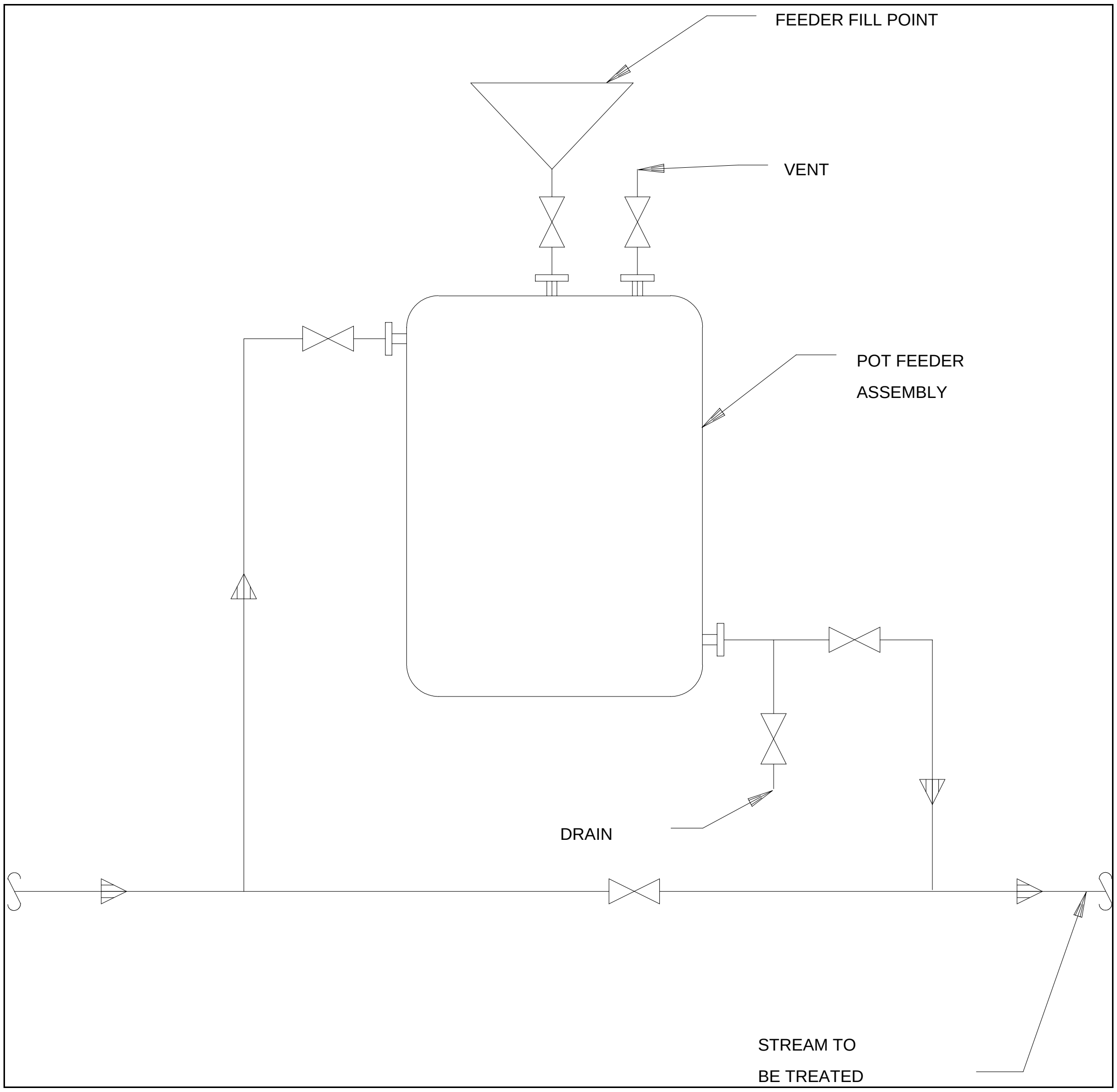


Figure 18-1. Typical fill system pot feeder installation

(3) The elevated temperatures at which even low-pressure boilers operate increase the likelihood of corrosion and scale formation problems from contaminants in the water. Other common boiler problems caused by poor water quality control are foaming and caustic embrittlement of metal components (usually not a concern for boilers operated below 600 psig). Steam boiler water quality control is typically accomplished by a combination of chemical treatment, deaeration, and blowdown. A typical steam boiler installation is shown on figure 18-4.

(a) In the example installation, the quality of the makeup water is adjusted by a water softener, a dealkalizer, or an ion exchange unit. In areas where only treatment to reduce hardness is required, a water softener is used to reduce the total dissolved solids in the makeup water that helps control scale formation and foaming. In areas where only treatment to reduce alkalinity is required, a dealkalizer is used. In areas where combined treatment is required, an ion exchange unit is

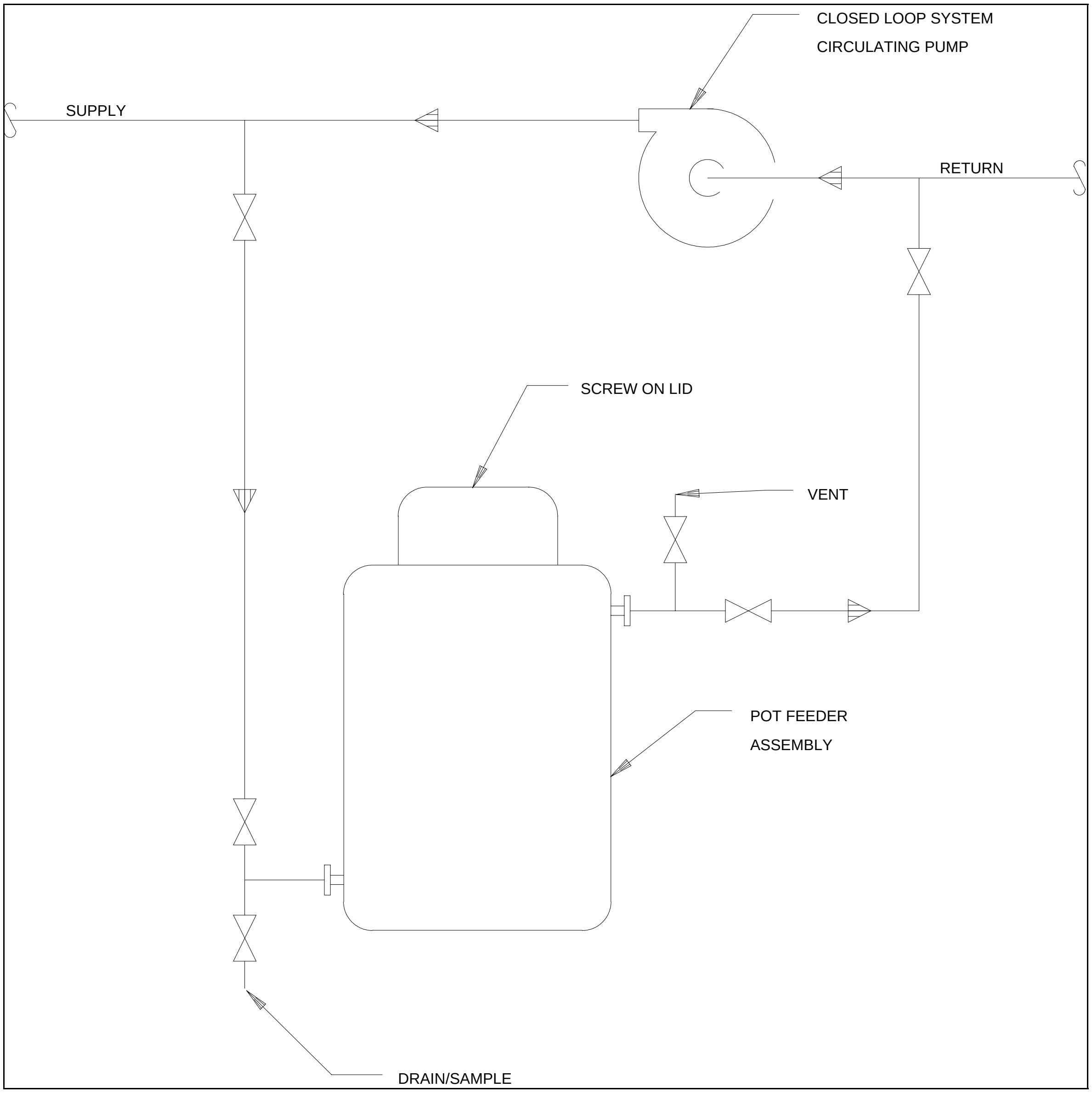


Figure 18-2. Typical pot feeder bypass installation

used. In an ion exchange unit, a section known as the cation exchanger removes metals, such as calcium and magnesium (hardness), and a section known as the anion exchanger (alkalinity control) may remove bicarbonates (corrosion and embrittlement), sulfates (hard scale), chlorides (foaming), and soluble silica (hard scale). A typical water softener unit is shown on figure 18-5, and a typical ion exchange unit is shown on figure 18-6. Dealkalizer units operate the same as water softeners, but use different resin bed materials and require strong caustic or acid regeneration. The makeup water is passed through a treated resin bed where the contaminants in the water are collected through a chemical exchange process. When the bed becomes saturated with contaminants, the bed is backwashed, treated with a concentrated electrolyte, rinsed, and placed back in service. For critical or continuous operations, treatment units may be dual-column units that allow switching from a saturated column to a regenerated standby column so

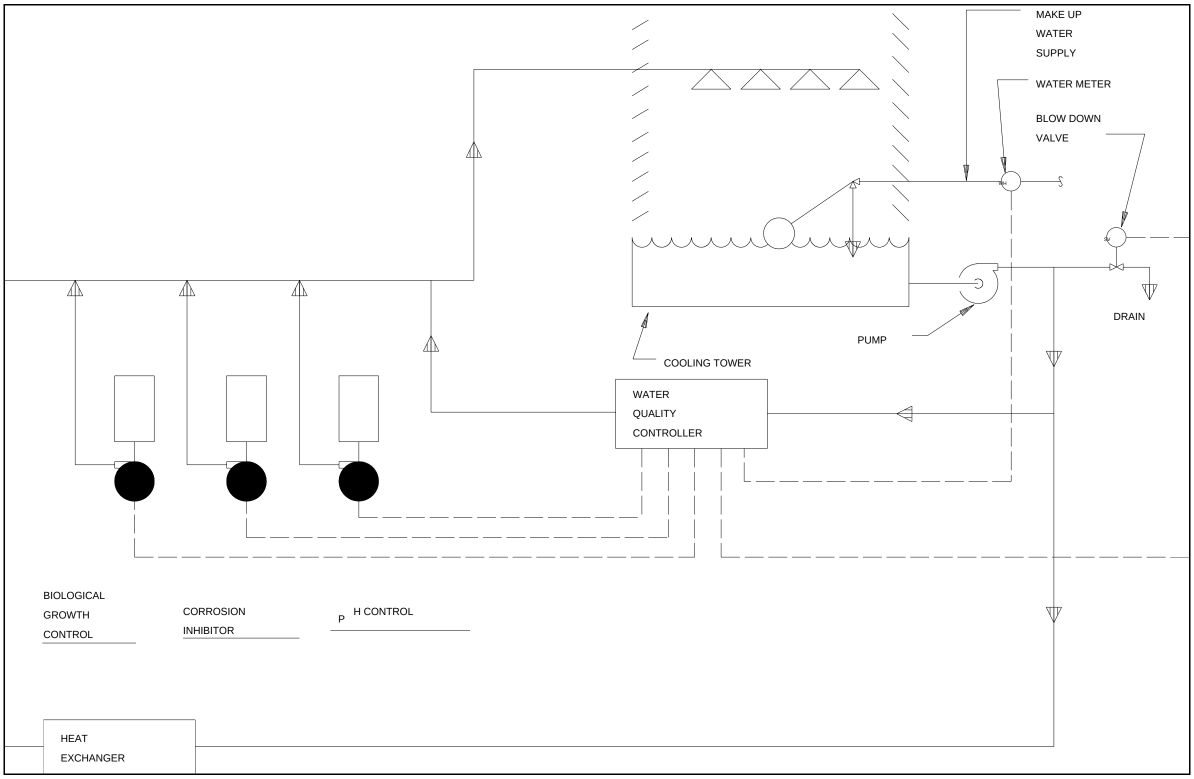


Figure 18-3. Open-loop chemical treatment system

that service is not interrupted for routine column regeneration. Ion exchange units may also be used to provide water for engine cooling systems and closed-loop process water systems. The use of water softener-treated water for engine cooling loops is discouraged by many engine manufacturers.

(b) The next step in boiler water quality control is deaeration of the combined makeup water and condensate return stream. A deaerator unit heats the water to the boiler point at the operating pressure of the unit which encourages release of non-condensable dissolved gases, such as oxygen and carbon dioxide, which are significant contributors to corrosion in the boiler and condensate system. As the feedwater flows from the deaerator to the boiler, various chemicals may be injected into the feedwater to further control corrosion, scale formation, foaming, and caustic embrittlement. (Some systems, as shown in the example, may also inject treatment chemicals into the steam header.) A typical feedwater treatment system consists of a chemical feed tank, an agitator, a strainer, a chemical feed pump, a check valve, and appropriate isolation valves. The operation and control of the metering pumps is dependent on the type of boiler and the boiler operation cycle, and the control options are similar to those discussed for open systems in paragraph 18-1c(2). Treatment chemicals such as hydrazine and sodium sulfite are used to control corrosion by reacting with dissolved oxygen and are generally referred to as oxygen scavengers. Chemicals known as neutralizing amines (injected into the feedwater) and filming amines (injected into the steam lines) provide protection against carbonic acid formed by the reaction of carbon dioxide and carbonates. Scale control chemicals generally act to keep precipitated solids soft and fluid.

(c) As water evaporates to form steam, contaminants are left behind which increase the concentration of total dissolved solids in the boiler. Even if fluid, a coating of solids on heat transfer

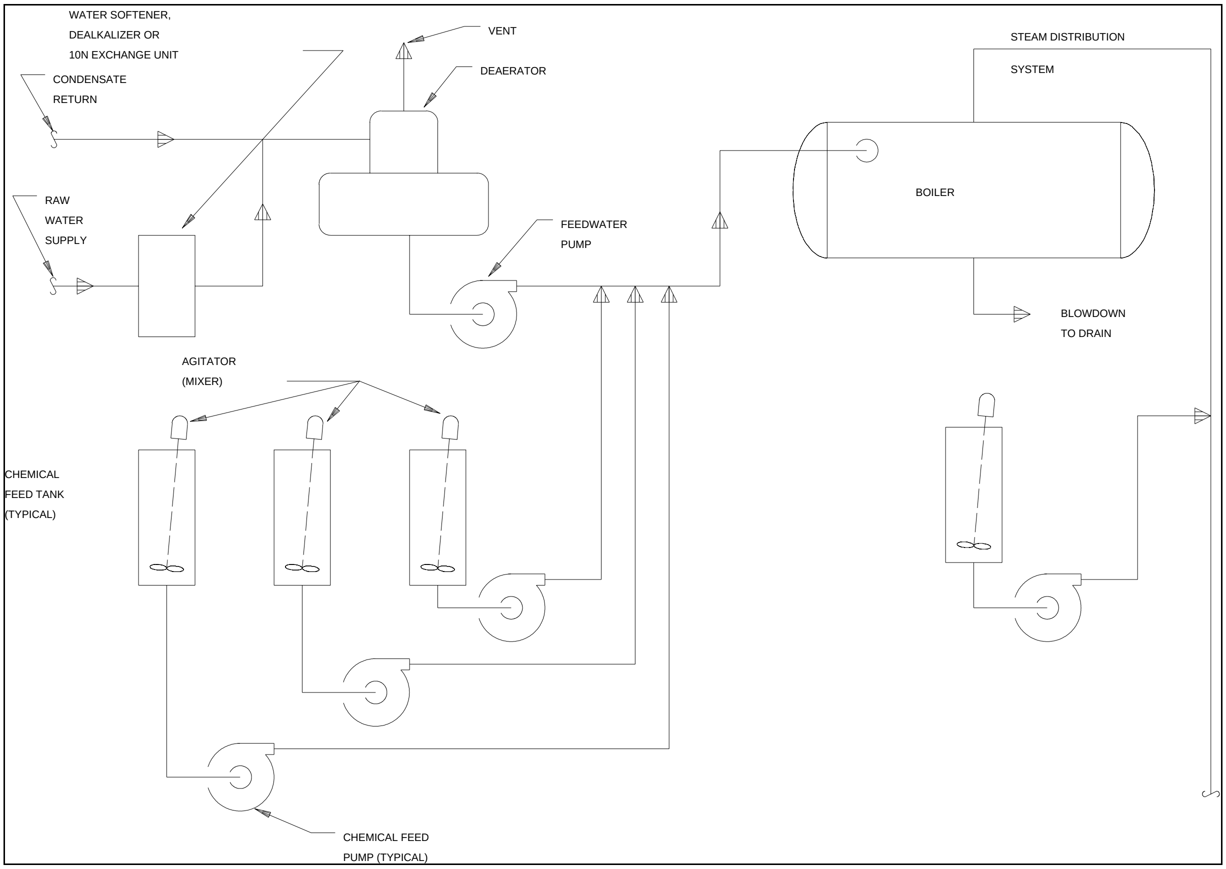


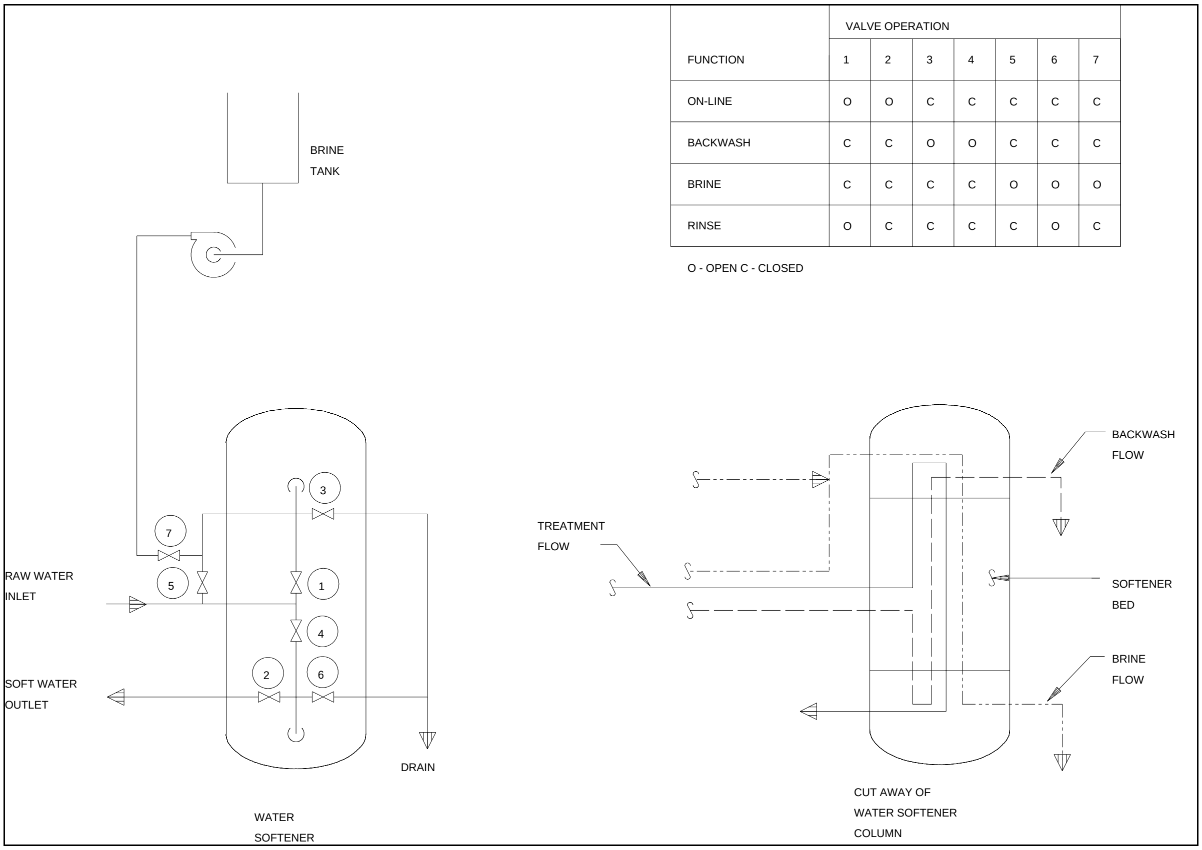
Figure 18-4. Typical steam boiler installation

surfaces, can reduce the capacity of equipment or create conditions which may lead to equipment failure. The concentration of total dissolved solids is controlled by blowing down the boiler. Boiler blowdown may be a combination of bottom blowdown and surface blowdown. Many boilers utilize a continuous or automated surface blowdown. Hot water boilers, which are used to provide hot water consumed in facility operations and, therefore, require substantial quantities of makeup water, may have makeup and feedwater treatment needs and blowdown operations similar to similarly sized steam boilers.

18-2. Chemical treatment system major components

Chemical treatment systems are comprised of the following major components.

a. Chemicals. The list that follows includes generic or families of chemicals which may be used to condition water and the typical condition that the chemical is used to treat. The specific name of the treatment product containing the listed chemical and the form of the chemical used will depend on the manufacturer. Most chemical treatment manufacturers have developed proprietary "brand names" which combine a number of the chemicals discussed below and include other agents to enhance the performance of the product. Facilities should use the technical service departments of water treatment chemical suppliers to tailor the facilities' chemical treatment needs to local conditions, and to establish procedures for safe chemical storage and handling.



FUNCTION	VALVE OPERATION						
	1	2	3	4	5	6	7
ON-LINE	O	O	C	C	C	C	C
BACKWASH	C	C	O	O	C	C	C
BRINE	C	C	C	C	O	O	O
RINSE	O	C	C	C	C	O	C

O - OPEN C - CLOSED

Figure 18-5. Basic water softener system

(1) Copper sulfate - Controls algae in reservoirs and open systems.

(2) Sodium hydroxide (NaOH - caustic soda) - Increases alkalinity, raises pH, precipitates magnesium.

(3) Sodium carbonate (Na_2CO_3 - soda ash) - Increases alkalinity and pH, precipitates calcium in the form of carbonate.

(4) Sodium phosphates (NaH_2PO_4, Na_2HPO_4, Na_3PO_4, $NaPO_3$) - Precipitates calcium as hydroxyapatite ($Ca_{10}(OH)_2(PO_4)_6$). Stream pH must be kept high for this reaction to occur.

(5) Sodium aluminate ($NaAl_2O_4$) - Precipitates calcium and magnesium.

(6) Chelants (EDTA, NTA) - Control scaling by forming heat-stable soluble complexes with calcium and magnesium.

(7) Polymers (polyacrylates, etc.) - Disperse sludge and distort crystal structure of calcium deposits. Prevent fouling due to corrosion products.

(8) Tannins, starches, glucose, and lignin derivatives - Prevent feed line deposits by coating scale crystals to produce sludge that will not readily adhere to boiler surfaces.

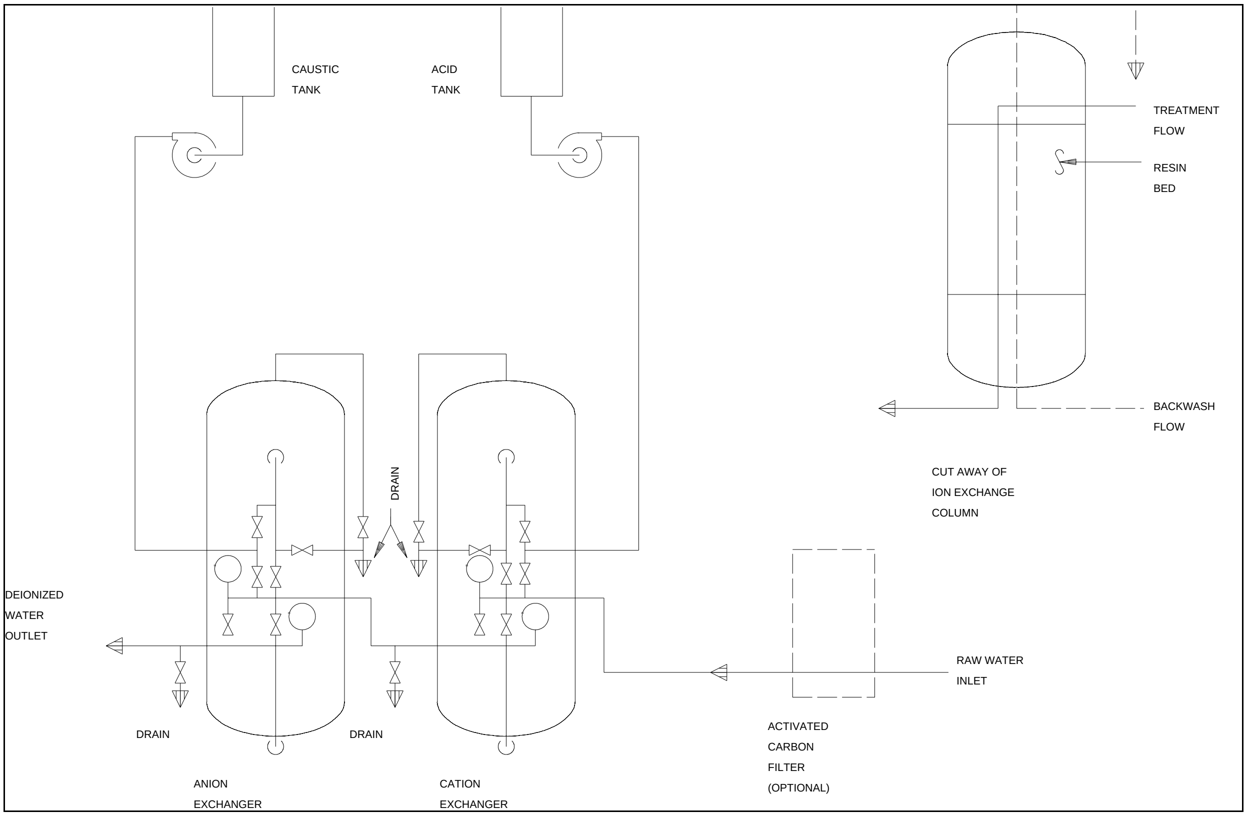


Figure 18-6. Basic ion exchange unit

(9) Seaweed derivatives (sodium alginate, sodium mannuronate) - Minimize carry-over from boiler by keeping scale forming sludge fluid.

(10) Sodium sulfite (Na_2SO_3) - Prevents oxygen corrosion.

(11) Hydrazine (N_2H_4 - normally supplied as a liquid) - Prevents oxygen corrosion.

(12) Filming amines (octadecylamine, etc.) - Control condensate line corrosion by forming protective film on metal surfaces.

(13) Neutralizing amines (cyclohexylamine, morpholine, etc.) - Control condensate line corrosion by adjusting condensate pH.

(14) Sodium nitrate ($NaNO_3$) - Inhibits caustic corrosion.

(15) Antifoams (polyglycols, polyamides, silicones) - Reduce foaming tendency of highly concentrated boiler water.

(16) Nitrite-borax (three parts sodium nitrite and one part borax) - Inhibits corrosion and controls cylinder line cavitation in diesel engine cooling systems.

(17) Soluble oils - Inhibit corrosion in diesel engine cooling systems.

(18) Chromates - Inhibit corrosion in diesel engine cooling systems. Not compatible with ethylene glycol base, antifreeze solutions and are extremely toxic. Do not use without major command permission.

b. Chemical feed pumps. Most chemical feed pumps are referred to as metering pumps. Because the pump has to inject a treatment chemical into what is frequently a high pressure stream, common chemical feed pumps are positive displacement units which use a reciprocating (piston) action to alternately fill a pumping chamber and discharge a fixed volume of solution. In many units, the piston acts through a flexible, noncorrosive diaphragm that isolates the mechanical elements of the pump from the chemical stream. Chemical metering pump discharge quantities can usually be varied by adjusting the stroke length of the pump by means of an external stroke length adjustment knob. The stroke adjustment of many electric motor-driven metering pumps alters a mechanical linkage that can be damaged if the pump is not operating when adjustments to stroke length are made.

c. Pot feeders. Pot feeders are used to add chemicals to systems that do not require frequent chemical treatment. The flow of the stream or part of the stream to be treated through a pot feeder charged with chemical solutions adds the chemical to the stream. Typical pot feeder installations are shown on figures 18-2 and 18-3.

d. Valves and piping. This paragraph presents an overview of the types of piping components and design and testing considerations related to chemical treatment piping. Information contained in this section applies to field-installed piping. Piping design, materials, fabrication, assembly, erection, inspection, and pressure tests for facility piping systems should be in accordance with American Society of Mechanical Engineers (ASME) B31.1, Power Piping. Major modifications of existing piping systems should include hydrostatic testing and radiographic or magnetic particle inspection of welds where applicable. During testing, system components that have not been designed for the piping test pressure must be disconnected and protected against damage by overpressure.

(1) Common valve materials compatible with typical facility chemical treatment systems are carbon or stainless steel. Valve bodies from these materials should be cast or forged. In low-pressure systems, plastic valves from materials similar to polyvinyl chloride (PVC) may be used. In general, unless the valve has failed after only a short period of use, replace valves (and other piping components) with new valves constructed from the same materials. Typical types of valves that may be found in chemical treatment systems are as follows.

(a) Gate valves may be used for lube oil shutoff service where a slow closure is acceptable and where absolute bubbletight closure is not a critical consideration. Gate valves may be rising stem, outside stem and yoke (OS&Y), or double-disk type.

(b) Ball or non-lubricated plug valves are generally used where quick or frequent opening or closing is required.

(c) Check valves are used in chemical treatment systems to prevent backflow through pumps, branch lines, meters, or other locations where runback or reverse flow must be avoided.

(d) Globe valves are used in systems at locations where manual control of the flow rate is required. General use of globe valves should be avoided, because of their high resistance to flow.

(2) Common piping materials used in chemical treatment systems are carbon steel pipe, and stainless steel pipe and tubing. Some low-pressure systems may use plastic pipe components. In general, when modifying or repairing a system, replace existing piping components or add to the system using piping components of the same materials of construction of the existing system, provided the service life has been good.

(3) Many piping systems will have one or more pipe test sections installed in the system. A test section is a short section of pipe that can be easily isolated and removed from the system to make a thorough visual inspection of the interior of the pipe system possible. Visual inspection confirms the need for or the effectiveness of a chemical treatment program.